

PROCESS METROLOGY PROGRAM

Device scaling has been the primary means by which the semiconductor industry has achieved unprecedented gains in productivity and performance quantified by Moore's Law. Until recently only modest changes in the materials used have been made. The industry was able to rely almost exclusively on the three most abundant elements on Earth — silicon, oxygen, and aluminum.

Copper is now predominantly the conductor of choice over aluminum because of its intrinsic higher conductivity. A variety of low-dielectric constant materials are being introduced to reduce parasitic capacitance, replacing silicon dioxide. As dimensions continue to shrink, the traditional silicon dioxide gate dielectric thickness has been reduced to the point where tunneling current has become significant and is compromising the performance of the transistors. This is requiring the introduction of higher dielectric constant materials. Initially the addition of nitrogen to the gate material is sufficient, but in the near future more exotic materials such as transition metal oxides, silicates, and aluminates are required. Additionally, the gate conductor, traditionally polysilicon, is being replaced by metal or metal silicide to eliminate the polysilicon depletion effect. With the replacement of the traditional silicon dioxide/polysilicon gate stack processes with materials capable of supporting ever shrinking geometries, the task of the industry becomes more difficult. The overall task represented by the projects below reflects the need for analytical techniques with unparalleled spatial resolution, accuracy, robustness and ease of use.

Accurate metrology of process gases is essential for reproducible manufacture of semiconductor products. Critical physical parameters need to be measured on a wide variety of reactive and non-reactive process gases, allowing the accurate calibration of flow meters and residual gas analyzers. Water and other contaminants at extremely low levels in process gases present serious manufacturing difficulties. Accurate calibration of water vapor at extremely low vapor pressures is required.

Atomic layer deposition processes are increasingly being used for high quality thin dielectrics and conductors. Techniques for understanding the deposition mechanisms and characterizing the compounds that are formed are being developed. Theoretical studies elucidating the thermodynamics and quantum mechanical properties of these compounds are being conducted.